Decreasing Sedimentation Loss from Surface Irrigation into Riparian Areas

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Sediment carried in furrow irrigation return flows is a large contributor of sediment to riparian areas in the Pacific Northwest (PNW). About 3.3 million acres are surface irrigated in Oregon, Washington and Idaho, nearly two million in Idaho alone (Anonymous, 1991). Furrow irrigation is an inherently erosive process, but sediment losses in the PNW are worsened by the steeper slopes and high erodibility of typical furrow irrigated fields in the region. Irrigation-induced erosion is one of the most severe threats to sustainability of agricultural production in the region.

Furrow irrigation-induced erosion commonly removes up to 22 tons/acre per year with a large part of this (as much as 3x the field averaged rate) occurring near the upper end of fields near furrow inlets (Berg and Carter, 1980; Kemper et al., 1985; Fornstrom and Borelli, 1984). Over 22 tons of soil loss per acre have been measured for a single 24 hr irrigation (Mech, 1959). Average field losses have removed over an eighth of an inch of topsoil per year from these irrigated fields. The magnitude of this problem is better appreciated when one recognizes that typical soil loss tolerance values for these soils are around 5 tons/acre per year.

The net result has been that in the 80-100 years that PNW furrow irrigation has been practiced, many fields have little or no topsoil remaining on the upper one third of the field. Furthermore the topsoil remaining on lower field portions is often mixed with subsoil washed off upper field reaches and deposited at the lower end. Of course, the negative impacts of this much soil loss are many fold.

The B horizons of PNW soils are typically high in calcium carbonates. When exposed at the surface by erosion, the light-colored areas are colloquially identified as "white soils". These calcarious horizons have poor chemical and physical properties. They easily crust, seal, and compact, and often have reduced P and Zn availability, as well as other micronutrient deficiencies. Consequently, they are less supportive of crop growth and production because of suppressed emergence, poorer fertility, reduced root exploration, and resulting impaired absorption of water and nutrients.

For many PNW soils, each inch of soil loss results in about 3-6 percent reduction in yield potential, depending on the crop grown (Carter, 1993). Thus, severely eroded portions of these PNW fields have less than 50 percent of their original yield potential remaining. As yield potential decreases, the cost of inputs increases, but the probability of getting response from inputs becomes less and less. Thus, the cost of production increases while the probable yield and profit declines, a formula for financial ruin.

A 1/8 inch topsoil loss (a typical yearly loss) equals about 22 tons per acre. This is soil that will deposit in the lower reaches of fields, clog drains and return-flow ditches, lakes, streams or rivers. Even if a significant amount of this sediment is captured in the lower reaches of the field or in sediment containment ponds, it will require redistribution in the field. The average sediment load carried during the period July 1990 through July 1991 by the Snake River increased approximately 65,000 tons between Murtaugh bridge and King Hill (Brockway and Robison, 1992). A large fraction of this increase was undoubtedly from agricultural field losses.

The societal costs of these losses include reduced net on-farm returns with resultant upward pressure on commodity pricing; higher cost of canal maintenance, river dredging, and algal control; riparian habitat degradation and biodiversity reduction; water contamination; impairment of fisheries and recreational resources; reservoir capacity reduction; and accelerated hydro-electric generator wear. Many of these expenses and losses are long range costs and are often neglected in cost benefit analyses for supporting conservation practices.

Because many of the true costs are hidden, and because the magnitude of irrigation induced erosion has been underestimated, public and individual support for conservation research and implementation in the West is lagging. Some of these attitudes stem from a traditional defensiveness aimed at maintaining congressional support for development of Western water projects. Some of the problem stems from lack of consensus on estimation procedures for irrigation-induced erosion. Regardless of the cause, the result has been that funding of soil conservation in the irrigated West has been seriously disadvantaged. Nonetheless, it is becoming increasingly clear that, both for reasons of enlightened self interest and due to environmental mandates, irrigated Western agriculture must now work harder than it ever has to reinstate and maintain the quality of its riparian resources.

Fortunately, a substantial body of research has already been accomplished to develop on-farm engineering and management practices to control or eliminate irrigation-induced soil erosion. Over the last two decades the research toward these practices has undergone a gradual evolution in emphasis. Initially the focus was containment of lost sediments before they could enter riparian areas. Subsequently, focus was prevention of soil loss from the farm. A parallel goal of both of these containment strategies was to enable replacement of captured sediment on farms suffering excessive soil loss, albeit at no small cost. The current research emphasis represents a shift from engineering practices toward development of crop management practices that are aimed simply at halting all soil movement, thereby retaining soil in place, eliminating any subsequent soil handling or transport.

Because every farm operation is unique, a given sediment containment practice may not be equally suited in all cases. Each farmer will need to determine which practice or practices will best suit his or her situation. Ultimately, erosion abatement practices that are used are more valuable in a given situation than practices that are not used, regardless of the relative theoretical effectiveness of a given practice. It is equally apparent, however, that in time, enforcement of clean water standards will probably demand that all return flows leaving a farm meet specified water quality standards. These standards may be voluntary standards, but may be tied to potent financial incentives or disincentives.

In Stanislaus County California, the West Stanislaus Hydrologic Unit Area Project has adopted a standard for return flows of 300 mg/l (Anonymous, 1994). This equates to about 814 lbs of soil carried away per acre foot of runoff. While this was seen as an ambitious goal at the outset of the West Stanislaus project, those involved have begun to express optimism that the goal is achievable. This progress has been possible in part because of California's stringent environmental laws but, more importantly, because of aggressive cooperation among California's state and federal environmental and conservation agencies. With equal cooperation and commitment to achieving this goal, irrigation return flows in the PNW could be greatly improved, perhaps even approaching these levels.

Below is a brief summary of erosion abatement practices that have already been thoroughly researched and are available now to combat sediment movement. They differ in ease of adoption, effectiveness, and cost of implementation, but from this list virtually every surface irrigated farm in the PNW can probably find one or more practices suited to their operation. These practices and related factors have been discussed in greater detail in several recent publications (Carter, 1990; Carter et al., 1993; Sojka and Carter, 1994).

Sediment Retention Basins: Sediment ponds can be large, perhaps 1/4 acre, and serving an entire 40-60 acre field, or small "mini-basins" that temporarily pond runoff for as few as 6-12 furrows. The basins reduce flow rates and briefly retain water, allowing deposition of many suspended particulates and reducing desorption of phosphorous. Retention basin effectiveness depends on sediment load, inflow rates, retention time, and texture of suspended particulates. About two thirds of solids can be removed from return flows, but only about one third of the total P (Brown et al., 1981). This is because clay, the most chemically active soil textural fraction is the smallest particle size class, and hence slowest to sink to the pond floor. Thus, the practice is more effective for medium textured soils, than for clayey soils.

Buried-pipe Erosion and Sediment-Loss-Control System: Buried drain pipes with vertical inlet risers allow tail water to pond at the bottom of fields until the water level initiates drainage into the riser. This will promote sediment retention in much the same manner as ponds, and is often an adjunct to mini-basins. The method is best suited to elimination of concave field ends. Effectiveness is near 90% while concavities or basins are filling, but drops to retention pond efficiencies once depressions are filled (Carter and Berg, 1983).

Vegetative Filter Strips: Cereal, grass, or alfalfa strips (10-20 feet wide) sown along the lower ends of row crop fields can reduce sediment in runoff 40-60%, provided furrows are not cut through the filter strip area. Filter strips can be harvested, but yields are usually 30-50% below normal for the strip crop (Carter et al. 1993).

Twin row and Close Row Planting: Planting corn as close as possible to both sides of an irrigated furrow to form twin row spacings reduced field sediment loss by about half in two years of observation (Sojka et al., 1992). Results for single but narrower than normal row spacings were more variable but showed promise for corn, sugarbeet and field beans. The effect results from a combination of factors including soil binding by roots in close proximity to the flow, introduction of plant litter into the furrow stream, and (with narrow rows only) systematic increase in furrow numbers (and hence wetted perimeter) and reduction of the irrigation set time needed to deliver equivalent quantities of water. This reduces the runoff stream size and runoff period relative to the total inflow.

Tailwater Reuse: For a modest capital investment, retention ponds can be enhanced to recirculate sediment-laden water into the irrigation supply. This does not halt or slow erosion per se, but to a degree it does automate the replacement of sediment onto fields from which they came. Advantages include maximizing water supply efficiency and 100% on farm sediment retention (Carter et al, 1993). Disadvantages are capital and energy cost and accelerated pump wear. There is also mingling of disease inoculum, weed seed, and chemicals, although these aspects occur where return flows are reused anyway. On a larger scale, however, many PNW surface irrigation companies and districts have been engineered with an assumption of return flows making part of the irrigation supply for large portions of the district. Complete elimination of return flows could dry up some reaches of existing systems.

Improved Inflow/outflow Management: Improved water scheduling, stream size monitoring (post advance flow reduction), improved field leveling, alternate furrow irrigation, etc. and infiltration measurement (soil water budget monitoring) could greatly improve water use efficiencies, thereby reducing both water application and runoff amounts, positively impacting erosion as a side benefit (Trout et al., 1994).

Furrow Mulching: Use of plant residue or living mulches in Furrows can be very effective at halting erosion. Permanent furrow sodding has proven nearly 100% effective at halting erosion (Cary, 1986) without adverse yield effects in barely, wheat, beans and corn. The technique required a special furrow cutter to maintain established furrows. Straw or other manageable residues can be selectively placed in furrows producing 52-71% sediment loss reduction (Miller et al., 1987; Aarstad and Miller, 1981; Brown, 1985; Brown and Kemper, 1987). Drawbacks of these techniques include very large increase in advance times and infiltration rates, and the addition of field operations for establishment and/or maintenance of the mulches, which can come at inconvenient times for crop managers, or cause problems during cultivation. Straw also sometimes moves in furrow streams, damming furrows and causing water to flow over rows into adjacent furrows.

Whey Application: Many irrigated areas are in close proximity to dairy processing plants. For many processors disposal of acid cottage cheese whey is a problem. Soil-applied acid whey both accelerates remediation of exposed subsoils and greatly (50-95%) reduces furrow irrigation-induced erosion (Robbins and Lehrsch, 1992; Brown and Robbins, 1995; Lehrsch and Robbins, 1994). The disadvantages of this approach are the cost and inconvenience of bulk hauling and field application of the whey. Costs might be born by processors, however, who are seeking land application sites.

Conservation Tillage for Furrow Irrigation: Field-wide erosion reductions greater than 90%, reduced production costs, and, in some cases, yield increases have been noted for a range of cropping systems using conservation tillage and no-till with furrow irrigation (Carter and Berg, 1991; Sojka and Carter; 1994). Once established, these systems may have the greatest potential for long range, cost-effective erosion elimination. The greatest disadvantage of this approach is the reluctance many farmers have to adopt such all-encompassing changes to their operation and even appearance of their farming operation.

Zone-subsoiling: Because irrigated PNW soils have been in production less than 100 years, compaction has only recently been recognized as a potential problem. Compaction deteriorates soil structure and impedes infiltration. Both impair crop production and contribute to runoff and erosion. Zone-subsoiling improves yield and grade of furrow irrigated potatoes while increasing infiltration up to 14% and reducing soil loss in runoff up to 64% (Sojka, et al., 1993a, 1993b).

Polyacrylamide-Treated Irrigation Water (PAM): During furrow irrigation, treating only the advance phase water with 10 ppm polyacrylamide (PAM) reduces sediment loss in runoff 85-99% while increasing infiltration 15% (Lentz et al., 1992; Lentz and Sojka, 1994; Sojka and Lentz, 1994). This translates to about 1 lb/acre per treated irrigation. PAM is an industrial flocculent used for food processing and water treatment, and is now marketed throughout the PNW for erosion control. Its advantages are consistent high effectiveness, low cost, and lack of major effects on other farming practices. With PAM, initial water application rate can usually be doubled, virtually without erosion, thus permitting greater field infiltration uniformity. Current drawbacks stem from the somewhat demanding mixing and application protocols required. PAM manufacturers are seeking to solve this problem via new product development.

Irrigation Water Quality (SAR, EC) Considerations: Recent research at Kimberly, ID has shown that elevated irrigation water sodium adsorption ratio (SAR), especially at low electrical conductivity (EC) can increase the erosivity of the furrow stream (Lentz et al., 1995). Sediment lost in runoff more than doubled when SAR 12 EC 0.5 dS m-1 water was used to furrow irrigate compared to using SAR 0.7 EC 2.0 dS m-1 water. Sediment loss increased 1.5 times, when compared to Snake river water (SAR 0.7 EC 0.5 dS m-1). Since many farms have more than one water source (e.g. well water and canal water) sometimes of varying water quality, it behooves the farmer to use less erosive water on steeper or more erosive ground, and/or to blend waters where feasible to reduce erosion hazard.

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